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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 112.
L. O. HOWARD, Entomologist and Chief of Bureau.

PRELIMINARY REPORT ON THE ALFALFA WEEVIL.

BY

F. M. WEBSTER,
In Charge of Cereal and Forage Insect Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., January 2, 1912.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 112 of this bureau, the manuscript of a preliminary report on the investigation of the alfalfa weevil in Utah and adjacent States. The investigations of the Bureau of Entomology in cooperation with the Utah Agricultural Experiment Station began April 1, 1910, and still continue. The period covered by this report is from April 1, 1910, to November 15, 1911. From April 1, 1910, to April 1, 1911, the bureau was represented in the investigations with but one assistant. Since that time the force has been increased until eight or nine persons have been from time to time employed. The information given is exactly what the title of the bulletin implies, preliminary in nature and not to be taken as conclusive in all cases. It is simply a short account of what has been done within the period of time just indicated.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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PRELIMINARY REPORT ON THE ALFALFA WEEVIL.

INTRODUCTION.

The alfalfa weevil belongs to a genus or group of beetles all of the members of which attack clover, alfalfa, and closely allied plants. Even before the appearance of this one, *Phytonomus posticus*[1] Gyll. (fig. 1), in our midst several other species had been introduced from Europe, had become established in our fields, and had spread to a greater or less extent over the country.[2] After becoming fully developed in early summer, all apparently have the same habit of scattering themselves over the country, a little later crawling into any secluded place that they can find, there to pass the winter. Years ago a lady residing in Michigan and spending the summer in New York, where one species of these beetles, *Hypera punctata* (fig. 2), was at the time very abundant, on her return home and on unpacking her trunk found some of them ensconced among the contents. They had in all probability secreted themselves, either in the trunk itself while it was being packed, or else among articles of clothing exposed out of doors prior to being packed in the trunk.

The alfalfa weevil is found in Europe, western Asia, and northern Africa, where, though it sometimes becomes abundant, it is not especially destructive. The foregoing will illustrate the numerous ways whereby it might have been introduced into this country in articles of commerce, in household goods, or among other belongings of immigrants coming from those countries.

FIRST APPEARANCE OF THE ALFALFA WEEVIL IN THE UNITED STATES.

The pest was first reported on the outskirts of Salt Lake City, Utah, in the spring of 1904. At that time it had seriously injured several acres of alfalfa, the first crop being damaged fully one-half and the second crop practically destroyed. The following spring, 1905, its work was observed several miles way. The particular locality where the pest was first observed is on the eastern border of the city. Although not far distant from nurseries, it is not in close

[1] In a recent paper, "The Genera Hypera and Phytonomus in North America north of Mexico" (Annals of the Entomological Society of America, vol. 4, no. 4, pp. 383, 473, pls. 24–34, December, 1911), Prof. E. G. Titus has given this species as *P. posticus* Gyll. *Phytonomus punctatus* had already been placed in the genus *Hypera* by European authors.

[2] *Phytonomus punctatus* Fab.: See Report of the Commissioner of Agriculture for 1881–82, pp. 171–179; *Phytonomus nigrirostris* Fab.: See Bul. 85, Part I, Bur. Ent., U. S. Dept. Agr., 1909. For other species of the genus see paper by R. L. Webster, Ent. News, vol. 20, pp. 80–82, 1909.

proximity to any railway; it is, on the other hand, among the habitations of the more humble class of people, such as have come from foreign countries. The correct inference, therefore, would seem to be that it was introduced with nursery stock or in the household effects of immigrants. The pest had gained a foothold, doubtless, years earlier, but had increased from perhaps a single pair and was too few in numbers to attract attention up to the time when it had become destructive over several acres and when it had probably spread in limited numbers far beyond. In the immediate vicinity of this seriously infested field, and indeed throughout the country about Salt Lake, alfalfa long ago escaped from cultivation and now grows as a weed generally on vacant lots (Pl. I, fig. 1) and other uncultivated areas like roadsides and railroad rights of way (Pl. I, fig. 2), so that it would now be impossible to determine, even approximately, the exact time and location of the original landing of the first individuals in Utah. As a matter of fact the insect might easily have been brought into the country again and again and have perished because the locality in which it ended its voyage was destitute of growing alfalfa.

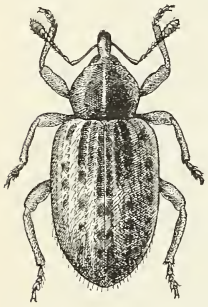

FIG. 1.—The alfalfa weevil (*Phytonomus posticus*): Adult. Much enlarged. (Author's illustration.)

SPREAD OF THE PEST.

From the single infested alfalfa field near Salt Lake, the only one known up to the year 1904, the pest evidently became somewhat widely diffused and by the following year was found several miles distant to the southeast. It was not, however, until 1907 that it was brought to the attention of the Utah Experiment Station and not until 1908 that attention was called to the matter in print by Prof. E. G. Titus,[1] entomologist of the Agricultural College and Experiment Station, although by the fall of 1907 it had spread over all of the alfalfa-growing section lying immediately east of Salt Lake and Murray.[2] By July 1, 1910, the infested area covered the greater part of Salt Lake and contiguous portions of adjoining counties, aggregating an area approximately 60 by 70 miles in extent.[3]

Up to September, 1911, the insect had extended its area of diffusion directly northward as far as Tremonton, east to Evanston, Almy, and Lyman, Wyo., and northeast to Cokeville, Wyo., Randolph and Laketown, Utah, and Fish Haven, Idaho.

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[1] Deseret Farmer, Salt Lake City, Utah, September 26 and October 3, 1908.

[2] Bul. 110, Utah Agr. Coll. Exp. Sta. The Alfalfa Leaf-Weevil, by E. G. Titus, Logan, Utah, September, 1910.

[3] Loc. cit., map 1.

INVESTIGATIONS BY THE UTAH EXPERIMENT STATION.

From the time the attention of the Agricultural Experiment Station authorities at Logan, Utah, was called to the pest and its destructive proclivities they began to investigate and experiment with a view of overcoming its ravages. Following the breeding season of 1909, however, the situation became so alarming as to make it clear that the State of Utah could not hope to cope with the pest single-handed. Besides, there was no longer a doubt that it would soon spread to alfalfa fields in other States, thus becoming a matter of interstate concern.

On August 4, 1909, his excellency William Spry, governor of Utah, appealed to the honorable the Secretary of Agriculture for assistance in controlling the insect and, if possible, preventing its spread into other States.

It was exceedingly unfortunate that this outbreak of the pest was not made known long before in order that it might have been investigated, for at this time it had become too widespread and destructive to be dealt with by any ordinary force of men. Besides, at this time the funds available with which to carry on investigations were wholly inadequate.

The appropriations made for the Bureau of Entomology for the fiscal year 1910–11 gave a slight increase of funds, $2,000 of which provided for cooperation with the State of Utah in investigation of the alfalfa weevil. None of this sum would, however, become available until July 1, 1910, after the season for the investigation of the insect had largely passed for the year. In view of the seriousness of the situation Mr. C. N. Ainslie was sent to Salt Lake, Utah, to take up cooperative work, April 1, 1910, lack of available funds prohibiting any further detail for the purpose.

At this time the entire cooperative force consisted of but two trained men, Mr. Ainslie, of the Bureau of Entomology, and Prof. E. G. Titus, of the Utah Agricultural College and Experiment Station, and Mr. Sadler, a student assistant, also from the experiment station.

From the fact that the experiment station people had carried out a number of field experiments against the weevil and had other experiments in view, and because of the bureau's limited funds for this work, it was deemed best that Mr. Ainslie devote his principal time to a close study of the insect itself and its habits, leaving the field experiments to be carried on by and under direction of the experiment station. The results and information thus obtained up to July 1, 1910, were embodied in Bulletin No. 110 of the Utah Experiment Station, by Mr. Titus, of which the author thereof has given the following synopsis:

The alfalfa leaf-weevil is a small, oval, brown snout-beetle, about $\frac{3}{16}$ of an inch long, that is attacking alfalfa in Utah. It is not a native species but has come to Utah from Europe.

It feeds on plants belonging to the alfalfa family, injuring all parts of the plant above ground.

The eggs are laid in the spring and early summer in the stems or on the buds and leaves, and hatch in about ten days. The young or larvæ are small alfalfa-green worms with a black head; they never become much more than one-quarter of an inch in length when full grown. They feed on and in the leaf-buds, in the stalks and on the leaves.

The larvæ have no true legs and have the habit of feeding or resting in a curled position.

When full grown, about 50 or 60 days after hatching, they go to the ground and spin around them a lace-cocoon, in which, in about fourteen days, they have turned into the full-grown, hard-shelled adult.

This adult feeds on the stems, leaves and buds for several weeks and in August goes into hibernation for the winter, seeking any well sheltered place.

The insect now occurs in Salt Lake, Davis, Weber, Morgan, Summit, Wasatch, Utah, and Tooele Counties, and threatens to eventually reach all our alfalfa growing regions. It spreads rapidly in the adult or beetle stage by flying in spring and summer and by being carried with articles shipped from an infested region, and on railroads, in wagons and automobiles, traveling through the places where it occurs.

It is recommended that alfalfa be disced in early spring to stimulate it to better growth. That the first growth be cut when the most of the eggs have been laid (middle of May), and then brush-drag the field thoroughly.

Sheep may be pastured on the fields at this time for two weeks, and alfalfa then watered and a good crop will usually be assured.

Gathering machines to capture the larvæ and beetles have given good results when used on the fields at the time the insects are most numerous.

Fields should be brush-dragged again after the first crop has been cut.

All weeds and rubbish should be cleaned from fields, yards, ditches and fence rows so that there will be less opportunity for the weevils to find winter shelter.

Alfalfa should not be allowed to grow more than seven or eight years in infested districts.

The amount of work that the Utah Experiment Station did with its limited means and lack of trained men is certainly most commendable, and it is difficult to see wherein the course adopted by the station director (Dr. E. D. Ball) and his subordinates could have been improved upon. It was from the beginning an unequal contest, and the only wonder is that so much good was accomplished with the limited means available.

COOPERATION OF THE BUREAU OF ENTOMOLOGY AND THE UTAH EXPERIMENT STATION.

There was the same basis of cooperation between the Bureau of Entomology and the Utah Experiment Station from April 1 until September 1, 1910, when Prof. Titus left the State, leaving Mr. Ainslie, and for a few weeks Mr. Sadler, to carry on the work. In the agricultural bill covering the fiscal year from 1911–12, under appropriations for cereal and forage insect investigations, $10,000 of this appropriation was made immediately available on passage of the act, to enable the bureau to take up investigations of the alfalfa weevil promptly in the spring of 1911. With the aid of

FIG. 1.—Volunteer growth of alfalfa on vacant lots in Salt Lake City, Utah. The alfalfa plant beside the hat contained at the time approximately 1,200 to 1,300 eggs. This was in the midst of the egg-laying time. (Original.)

FIG. 2.—Volunteer alfalfa growing along the right of way of the Oregon Short Line Railway a short distance north of Salt Lake City, Utah. (Original.)

this fund, on April 1 a corps of entomologists was sent to Salt Lake City, Utah, for the purpose of carrying out a thorough study of the insect and its ravages, with special reference to methods of control. Gradually other assistants were detailed, until the number employed in and about Salt Lake was increased to nine, exclusive of the student assistant detailed from the State Agricultural Experiment Station.

The primary object of this work was, so far as possible, to restrict the insect to the area it then occupied and to use every effort, by field experiments in measures of control, to devise means of lessening its destructiveness.

In the meantime it has been learned definitely that the alfalfa weevil was largely held in check in its native home by its natural enemies. Mr. W. F. Fiske, in charge of the Gipsy Moth Parasite Laboratory, having been detailed for work in Italy, kindly volunteered to look into the matter of natural enemies of the weevil and, so far as was possible without interfering with his other duties, to send over to this country any insect enemies that seemed to him susceptible of colonization in Utah. The object of this was to get these insect enemies established, in so far as it was practicable to establish them, at the earliest possible date, in order that they might have the opportunity to diffuse themselves during the spring of 1911. The value of Mr. Fiske's services at this time and in this direction can hardly be overestimated. A more detailed account of this matter will be found under a discussion of the introduction of the natural enemies of the alfalfa weevil.

Very naturally the alfalfa weevil work divided itself into two branches: (1) The field work, which included all mechanical measures for controlling the pest in the field; and (2) the work, necessarily carried out largely in the laboratories at first, involved in the care and management of the parasitic material dispatched by Mr. Fiske from Italy. After the beginning of the fiscal year 1911–12 the experiment station was able to add but slightly to the force of investigators. By this time, however, the annual generation of the weevil had developed to the adult stage and laboratory investigations had largely decreased.

While, as shown, the experiment station, owing to circumstances not under its control, was not able to put into the field men trained for this kind of work, the bureau was able by the aid of the immediately available fund to overcome this difficulty. In the meantime, however, the experiment station did its full share in other directions. Dr. Ball, director of the station, did not hesitate to use his personal and official influence whenever and wherever it could be of service in advancing this work. Besides this, in a great many cases he was able to relieve the bureau of expenses of field investigations as well as to carry a number of other items of expense for which it would

have been impracticable for the bureau to have provided. It may be stated, then, that from April 1 to September 1, 1910, the cooperative work was largely under the direction of Prof. E. G. Titus of the experiment station. From September, 1910, to April, 1911, it was mostly carried on personally by Mr. C. N. Ainslie. During the spring and summer of 1911 the investigation was carried on under the general direction of those connected with the Bureau of Entomology. Outside of the work on parasites, which has been carried on wholly by the bureau, it is not possible distinctly to indicate just what part of the cooperation was carried on by either the bureau or the experiment station. This combination has been for the purpose of accomplishing the greatest amount of good, and there has been no inflexible line separating the work of the two cooperative bodies. As a matter of fact, the results obtained could not have been secured under any other arrangement or with less unselfish feeling than has existed among those engaged in the investigation.

COOPERATION WITH OTHER BUREAUS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

Observations made by Mr. W. F. Fiske in the vicinity of Naples, Italy, during the spring of 1910 appeared to indicate a possible preference on the part of the alfalfa weevil for certain varieties of alfalfa. Those varieties, notably, having a slender stem appeared to be less freely attacked as compared with those varieties having more robust stems. It was with the view of perhaps being able to find a variety of alfalfa more or less objectionable to the alfalfa weevil that a cooperative experiment was taken up with the Bureau of Plant Industry.

Variety Experiment.

The Chief of the Bureau of Plant Industry, therefore, detailed Mr. Roland McKee, of the Office of Forage Crop Investigations, to superintend the seeding of a number of varieties of alfalfa (*Medicago sativa*) and the following closely related species: *Medicago falcata* L., *M. ruthenica* (L.) Trautv., *M. lupulina* L., *M. ciliaris* (L.) All., *M. echinus* Lam., *M. hispida nigra* (Willd.) Burnet, *M. hispida confinis* (Koch) Burnet, *M. hispida terebellum* (Willd.) Urban, *M. muricata* (L.) All., *M. orbicularis* (L.) All., and *M. scutellata* (L.) Mill. The tests of these varieties are being conducted on a farm in the vicinity of Salt Lake City, Utah.

Such observations as it has been possible to make upon the young plants involved in this experiment will be found recorded under food plants. It will of course be understood that the most valuable and decisive information bearing upon the relative extent of attack in these different varieties of alfalfa can not be observed until the spring of 1912. Therefore the information now given must be regarded as only initiative.

Investigations of Vertebrate Enemies.

In order to determine what assistance might be expected from birds and other animals besides insects, arrangements were made with the Biological Survey to send an assistant to Salt Lake in order to carry out extended investigations along this line. Mr. E. R. Kalmbach was detailed for this work by the Chief of the Biological Survey and proceeded to Salt Lake, Utah, making continuous observations there from May 7 to July 5, 1911.

It is not possible at the present time to give the results of this work in detail, but a list of the vertebrate enemies observed attacking the alfalfa weevil will be found under the heading Natural Enemies.

THE INSECT NOT CORRECTLY DETERMINED.

In the bulletin of the Utah Experiment Station, to which reference has already been made, the name of the insect is given as *Phytonomus murinus* Fab., and this name was also applied to the same insect by the writer in Circular No. 137 of the Bureau of Entomology, issued April 20, 1911. It had been so determined by one of the best American authorities on this order of insects. It has, however, proved to be a closely related insect (*Phytonomus posticus* Gyll.), much more common and injurious to alfalfa in Europe, western Asia, and northern Africa, and in these countries known generally as *P. variabilis* Hbst., meaning literally the variable Phytonomus. It is, however, less destructive in the Eastern Hemisphere than it bids fair to be in this country, because of its natural enemies at home, which, as it appears, were not brought over with it when it was first introduced.

APPEARANCE OF A SECOND SPECIES IN UTAH.

A much larger species, *Hypera punctata* Fab. (fig. 2), the clover-leaf weevil, has recently been found about Malad, Idaho, by Mr. H. T. Osborn, and about Ogden, Utah, by Mr. E. J. Vosler, both of this bureau. This is a larger insect than the alfalfa weevil, but may be confused with it by the ordinary farmer. It had not before been observed between the Rocky Mountains and the Cascades.

While known as a clover insect, this last beetle did some damage to alfalfa in Virginia during June, 1910.

DESCRIPTION AND SEASONAL HISTORY OF THE ALFALFA WEEVIL.

The fully-developed alfalfa weevil, *Phytonomus posticus* Gyll. (fig. 1), is a small, rather insignificant appearing beetle, slightly under one-fourth of an inch long, of a brown color, mixed with gray and black hairs arranged in indistinct spots and stripes on the back, as shown in figure 1. Rubbed individuals may be very dark, verging on black.

The beetles pass the winter hidden away among matted grass or other similar vegetation, including alfalfa, and, indeed, among most kinds of rubbish anywhere, wherever they will be protected from the weather. The beetles have also been found in early spring under clods and about the crowns of alfalfa plants where the ground had been roughly cultivated the previous autumn. The overgrown margins of fields and irrigation canals and ditches afford excellent places for hibernation, some of which are shown in Plate II, figures 1, 2, and 3.

With the first warm weather in spring the beetles become active and diffuse themselves over the alfalfa fields, feeding upon any living part of the plants that have escaped the winter or, as soon as it commences to push forth, on the fresh growth, both leaf and stem. During some years the beetles are abroad in the fields in Utah early in March; in other and colder springs it may be April before they bestir themselves. Latitude and elevation, with the consequent modifications of temperature, will have much to do in deciding the time of emergence from winter quarters in spring. They also to some extent hibernate in the alfalfa fields.

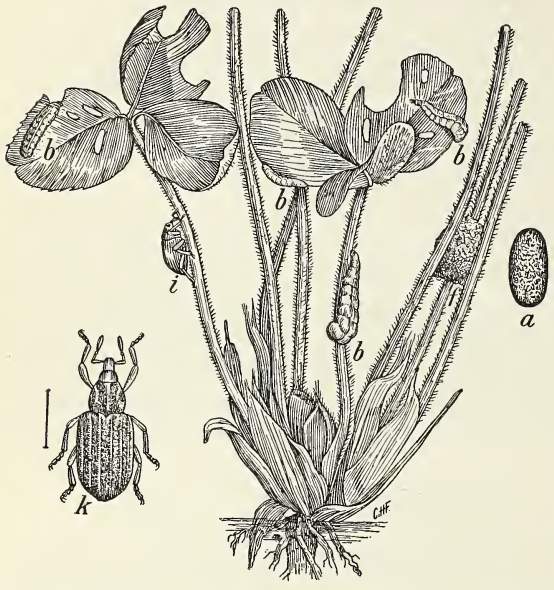


FIG. 2.—The clover-leaf weevil (*Hypera punctata*): *a*, Egg; *b*, *b*, *b*, *b*, larvæ feeding; *f*, cocoon; *i*, beetle; *k*, same, dorsal view. (*b*, *f*, *i*, Natural size; *k*, enlarged; *a*, greatly enlarged.) (From Riley.)

As soon as the beetles have spread from their winter quarters out over the fields they pair, and the females are ready to deposit their eggs (figs. 3, 4). As a matter of fact, however, pairing has been observed in the fall, and females taken while hibernating are observed to lay 75 per cent of fertile eggs. According to the notes of Mr. Fiske, made in Italy, they may place their eggs in the old, dead, overwintered stems or even in the dead stems of plants other than those of alfalfa, but in Utah the beetles refused to oviposit in dead stems in the laboratory cages. According to Dr. Giovanni Martelli,[1] at Portici in 1909 the first adults which he obtained appeared toward

[1] First contribution to the biology of *Phytonomus variabilis* Herbst. Bollettino del Laboratoria di Zoologia Generale e Agraria della R. Scuola Superiore d'Agricoltura in Portici, vol. 5, March, 1911.

FIGS. 1 and 2.—Hibernating places of the alfalfa weevil along fences and borders of fields in the vicinity of Salt Lake City, Utah. (Original.)

FIG. 3.—One of the main irrigation ditches in the Salt Lake Valley, a favorable hibernating place for alfalfa weevils. Photographed July 7, 1911. (Original.)

HIBERNATION OF THE ALFALFA WEEVIL.

the end of April; at Acicastello in 1910 they appeared during the first part of the second half of April. The maximum birth at Portici in 1909 took place toward the end of the second decade of May and the last adults were hatched near the end of May. At Acicastello the maximum birth took place in the first decade of May and the last were hatched during the second decade of the same month.

The females do not, however, always confine themselves to alfalfa stems in ovipositing. On April 18, 1911, Mr. T. H. Parks found eggs of Phytonomus in punctures similar to those made in alfalfa in the stems of the ground plum, *Astragalus arietinus*. Later Mr. C. N. Ainslie found a number of these eggs in similar punctures, also in the stems of this plant, there being usually six or eight eggs in each puncture. Afterwards Mr. Ainslie found larvæ feeding on *Astragalus utahensis*.

A few days before, Mr. Parks had also found eggs deposited on the surface of leaves, on bits of trash, on the inside of a split stem of grass, and, in one case, upon the bare ground.

In a very early spring some of the eggs may be deposited outside of the plant, but evidently this is not usual and occurs mostly when the growing stems of alfalfa are too small or not sufficiently numerous to satisfy the requirements of the females in this direction. In preparing for egg deposition the female punctures the stem with her beak. The punctured stems and a group of these eggs in place are shown in figure 4.

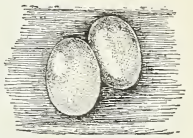


FIG. 3.—The alfalfa weevil: Eggs. Greatly enlarged. (Author's illustration.)

The method of oviposition has been described by Mr. Titus.[1]

Observations were made by Mr. C. N. Ainslie in which he found that oviposition seemed to be accomplished by forcing the beak into the fleshy tissues of the stem, sometimes into a hollow stem, in which case the eggs are merely placed in the natural cavity. Where placed in a leaf petiole, as is sometimes the case, the cavity for the eggs must be necessarily eaten out. Generally in these eaten cavities only 4 or 5 eggs are placed, while in the hollow stems 15 or 20 seem not uncommon. Once or twice Mr. Ainslie found eggs placed below the enlarged base of the petiole. In this case the eggs were placed in position through a hole made through the base of the petiole and the mass of eggs was well protected by the hairy leaf buds and unfolded leaflets behind the base of the petiole. Once in a while the hole into the stem is eaten and the beak not merely forced in, in which case the gleam of the yellow eggs can be seen through the tunnel into the stem. When the opening is forced it is left more or less filled with fibers that have been disrupted or forced aside by the beak and the ovipositor. These fibers are often blackened from

[1] Bulletin 110, Utah Agr. Coll. Exp. Sta., pp. 38-39, September, 1910.

some cause, perhaps simple oxidation, and appear quite different from the "feeding holes" that are much more common. These latter are either saucer or cup shaped cavities eaten into the plant stem or punctures through the epidermis that are enlarged inside the stem.

In one alfalfa stem Mr. Ainslie found 4 egg "nests," the holes being in pairs. These pairs were one-half to three-fourths of an inch between the separate holes, and each pair was in a separate node, the pairs perhaps 3 inches distant from each other. There must have been 30 or 40 eggs at least in this one stalk. It was picked from a vigorous crown growing beside a manure pile, and nearly every other stem in this crown contained eggs. These shoots were tall and had evidently grown rapidly. Indeed this seems to be the kind of stem chosen by this insect in which to place the eggs; shorter, woodier stems seem seldom to be selected for this purpose

FIG. 4.—The alfalfa weevil: Larvæ attacking a sprig of alfalfa, and eggs, *in situ;* larva, enlarged, at right. (Author's illustration.)

As observed by Messrs. Wilson and Parks, assistants of the bureau, the female beetle, after excavating the cavity for the eggs, inserted her ovipositor and laid a number of eggs before removing the ovipositor from the cavity. After this she began beating it up and down rapidly over the puncture as though pounding the orifice, sometimes but not always excreting a drop of watery material over the puncture. This secretion when hardened appeared to seal the opening. In some cases the arrangement of the eggs in rows on each side of the puncture, as described by Mr. Ainslie, was verified.

Mr. Titus has described the egg [1] as being oval, rounded at the ends, and when first deposited lemon-yellow in color. As the eggs incubate they become darker at one end and a deeper yellow in the other

[1] Bulletin 110, Utah Agr. Coll. Exp. Sta., p. 34, September, 1910.

portions. Under the microscope the surface of the egg is very slightly roughened and sculptured.

Mr. Ainslie, who made a careful study of the egg (fig. 3) at oviposition and later, found that at time of laying the egg was a mere sac, the shell being little more than a transparent, homogeneous envelope or membrane. As segmentation proceeded this membrane became very faintly pitted, and under the microscope with proper illumination barely discernible reticulations, both pentagonal and hexagonal, were apparent. Both ends and sides seemed equally reticulated, the areolation being perhaps a little smaller at the ends. After the larva emerges the shell that remains is a transparent structureless membrane with no trace of reticulation.

The number of eggs placed in a cavity varies greatly, there sometimes being not more than 2 or 3, ranging up to over 30; probably 10 would be about the average number, although these figures are of course only approximate. Mr. Parks found that during the first half of April the number ranged from 3 to 18, averaging 7 or 8; during the last half and early May the number increased, 25 or 30 being the maximum, with an average of 8 or 9. With reference to the number of eggs that may be deposited in a single alfalfa plant, the one shown beside the hat in Plate I, figure 1, examined on April 23—at which date oviposition was still in progress and the beetles preparing for oviposition were still exceedingly numerous in the fields—indicated that this plant at this date contained nearly if not quite 1,300 eggs. Of course, in fields where the alfalfa grew up thickly there would be a relatively less number per plant, but these figures serve to illustrate the origin of the countless myriads of larvæ that swarm over the plants in an alfalfa field and render more easy of comprehension the destruction shown in Plate III, figure 1. The difference between uninjured and affected plants is shown in Plate III, figure 2, *a* and *b*. Other ravaged fields are shown in Plate IV, figures 1 and 2, in contrast with figure 3 of same plate.

In the Salt Lake Valley oviposition has been found to take place earlier on the bench lands than lower down in the valley itself.

Egg-Laying Period.

The period of egg laying is a matter of considerable significance, since in some degree it will decide the question of efficiency or practical measures of control. As is usual with insects, after a female has exhausted her supply of eggs she dies and there is no second depositing of eggs by her during that season. The actual time required for the individual female to deposit her supply of eggs is of course influenced by the weather. In 1909 egg laying began in the fields early in April, and eggs were found in greatest abundance during the last of May and the first of June. In 1910 egg laying began early

in March and was at its height by the middle of May, and Mr. C. N. Ainslie found eggs in a rearing cage where beetles were confined indoors as late as October 22, and others found them as late as November 10, and Mr. E. J. Vosler on December 6, while larvæ of all sizes were found rarely in the fields November 1. On this latter date the sexes were pairing in the fields and some of the females contained apparently mature eggs, but none could be found deposited in the fields. In 1911 Mr. Urbahns found eggs and very young larvæ March 31, and adults active in the field on a warm day (January 31, 1912); one feeding and one pair mating.

The time required for the eggs to hatch after being deposited is, according to Mr. Titus, from 7 to 16 days, as observed by Mr. Ainslie about 10 days, and according to Mr. Parks's observations about 13 days. The three series of observations were made during different years, 1909, 1910, and 1911, and, of course, under different temperature conditions. It would seem as though more or less pairing is done in very late fall and the eggs deposited the following spring. Of course, the scattering eggs and larvæ found throughout the late summer and fall have little economic importance except to indicate what might be expected in more southern localities, although even in Utah some eggs probably survive the winter.

Evidence of a Partial Second Generation.

The occurrence of larvæ up to the approach of cold weather in late fall has already been noted. Some of these at least might be accounted for from the fact that overwintering females still containing eggs are found throughout July and early August; but that others of these larvæ are the offspring of parents developing during the preceding spring is strongly indicated by the fact that the females depositing eggs from which larvæ afterwards hatch are in perfect condition, unrubbed, and apparently fresh.

Under date of October 19, 1910, Mr. Ainslie found that eggs were being deposited in his rearing cages, dropped at random on stems and leaves and even on the sides of the cage, but in no case did he observe them placed within the stem. There were in this cage 150 adults, some of which were undeniably trim and fresh as though they had just emerged, while others were pretty well worn, and there were all intervening gradations. Adult females swept from alfalfa November 2 were found to have oviposited two days later. Adults taken from the fields November 7 and kept indoors were found to have deposited eggs within 2 or 3 days prior to November 30.

During the season of 1911 it was possible still further to substantiate the foregoing by an extensive series of observations carried on by several of those engaged in the investigation, and besides to add even more evidence that some of these late-appearing larvæ are the

FIG. 1.—One of the worst infested fields in the Salt Lake Valley, showing injury to the first crop of alfalfa, which was left uncut. Photographed June 26, 1911. (Original.)

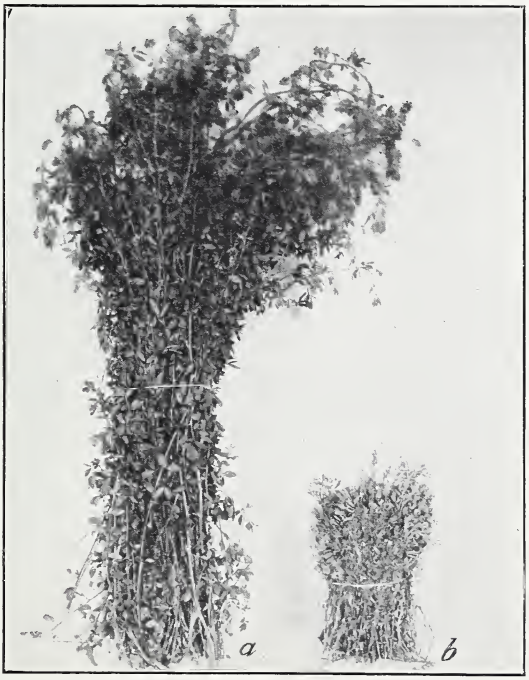


FIG. 2.—*a*, Bunch of alfalfa uninjured by the alfalfa weevil. *b*, Bunch of alfalfa badly injured by the alfalfa weevil, showing growth made by first crop in the badly infested fields. Photographed June 20, 1911. (Original.)

INJURY WROUGHT BY THE ALFALFA WEEVIL.

FIG. 1.—Crop secured from first cutting of one of the worst infested fields. Photographed June 9, 1911. (Original.)

FIG. 2.—First cutting from another field damaged from attack by the alfalfa weevil. Photographed June, 1911. (Original.)

FIG. 3.—First cutting secured from one of the fields of alfalfa slightly injured by the attack of the weevil. Photographed June 2, 1911. (Original.)

INJURY WROUGHT BY THE ALFALFA WEEVIL.

offspring of parents developing during the preceding spring. Eight apparently fresh adults taken from the field on August 18 by Mr. Urbahns were observed on the 21st to have oviposited to the number of about 20 eggs, in confinement. Nine additional eggs were found on the 23d. August 29, 10 adults, also seemingly fresh and unrubbed, were confined in a glass vial, and the following day about 50 eggs were found in the vial. Under the same date 112 beetles, supposed from appearances to belong to the spring generation, were collected by another member of the force at an elevation of about 7,000 feet, and the following day 75 eggs were found in the box in which they were confined. Under the artificial conditions not all of these eggs hatched. This state of affairs continued and was observed by several of the men to occur up to the end of the season.

While the beetles go into hibernation in nearly perfect unrubbed condition, they emerge in spring with scales and pubescence removed to such an extent that they are almost black in color, smooth, and shining. This appearance so contrasts with that of the newly-emerged adults of the new generation that the latter can be easily separated at sight, and it was these latter that were again and again observed to oviposit and their eggs to hatch out larvæ.

FIG. 5.—The alfalfa weevil: Larva. Much enlarged. (Author's illustration.)

THE LARVA.

The larval stage is shown in dorsal view in figure 4 and in lateral view in figure 5. It is during this stage that the pest accomplishes the greatest destruction, although the beetles are of themselves capable of ruining the second hay crop of alfalfa.

Mr. Titus [1] states that soon after hatching from the eggs the larvæ, which at that time are quite active, begin feeding in the interior of the stalk, sometimes remaining there for 3 or 4 days, and isolated examples have been found that have passed into the second stage, still inside the stalk. Larvæ have been found inside hollow stems several inches away from the place where they hatched, working their way upward, and later issuing through a feeding puncture. Usually after 3 or 4 days they come out and work their way up the outside of the stems and conceal themselves in a leaf bud, usually at the tip of the plant.

That the very young larvæ are capable of traveling considerable distances to reach their food supply is not only indicated in Mr. Titus's published statement, but emphasized by the observations of Mr. C. N. Ainslie under date of April 28, 1910. The actions of newly hatched

[1] Bulletin 110, Utah Agr. Coll. Exp. Sta., pp. 39, 40, September, 1910.

larvæ, as observed by him, were remarkably vigorous, very young ones exhibiting great energy as travelers. Their mode of progression is to reach forward and then, with a slight hump, to bring up the rear part of the body. The head is at once thrust forward again. About one move is made per second, and three propulsions will carry the body forward 1 mm. When in doubt as to the direction to be taken, the larva elevates the head and swings it from side to side until some decision is reached, when the journey is resumed. The larvæ are positively phototropic.

After working their way upward on the alfalfa stems the larvæ begin to feed close down between the opening buds on the unfolding leaves. Their manner of feeding there, as observed by Mr. Ainslie, was by scraping off the epidermis with a sort of burrowing motion, leaving only the veins and fragments of uneaten tissue. This selection of the terminal buds may be in part due to the shelter offered as well as to the more tender and succulent nature of the plant growth. Large numbers of young larvæ may, however, be found feeding among the unfolding buds without being easily seen. This feeding is further described by Mr. Titus [1] as follows:

> In feeding, the larvæ bore holes into the buds [see fig. 4], working their way in until they are often completely concealed inside the opening bud. The plant then sends out other buds below this point, and usually other young larvæ are present to destroy these, so that at times the growing tips of the plants become so injured as to give these tips the appearance of a gall. As many as 15 young larvæ have been found feeding in the terminal bud of one stalk. Sometimes, before they are fully developed, in the second stage, they pass out onto the leaves, at first eating the upper epidermis only.

The larvæ, after the usual habit of those of the genus to which it belongs, either cling around the edge of the leaf or feed in a curved position. This continual eating off of the fresh growth keeps the alfalfa so reduced that it does not produce a first crop. Seriously affected fields are shown in Plate III, figure 1, and Plate IV, figures 1 and 2, while a field that has not suffered from such attack is shown in Plate IV, figure 3. From these illustrations a good idea of the damage done by the larvæ to the first crop of alfalfa may be obtained.

LARVAL PERIOD.

From about 5 to 8 days after hatching from the egg the skin of the larva splits and the old skin is pushed off, leaving the larva in a new dress. This process is repeated after a period of from 12 to 20 days and again after about 12 to 30 days, as observed by Mr. Titus. Mr. Ainslie in some instances got pupæ in 18 to 20 days during May, 1910. These variations in time are probably largely due to temperature, which again may be due in part to elevation.

[1] Bulletin 110, Utah Agr. Coll. Exp. Sta., pp. 40–42, September, 1910.

When the larva is fully grown, it ceases to feed and seeks out some place in the crown of the plant among the litter and trash or on the ground among similar material, where it spins a cocoon (fig. 6).

Cocooning and Pupating.

The cocoon is composed of fine white threads and the construction by the apparently blind larva was in part observed by Mr. Ainslie, who describes its movements as follows: A larva was seen moving about in its snow-white, almost transparent, gauzy, unfinished cocoon. It proved to be spinning a closer mesh from within. Instead of spinning the silk from a gland that opened into its mouth, as was supposed, the fluid from which the silk is made is taken into the mouth apparently from a gland in the caudal segment. The larva applied its mouth to an opening or gland close to the anus, appeared to move its jaws slightly, and then, with a quick movement of the body, was straightened out as much as possible in its confined space, and instantly the head was applied to the inner network of the cocoon. A slender glistening thread was seen leaving the mouth, being attached glutinously to each thread that it crossed. The larva worked rapidly and nervously, nearly always carrying its new thread in a rather straight line. From 30 to 50 seconds were required to discharge a single mouthful supplying thread for one-third or one-half a revolution inside the cocoon.

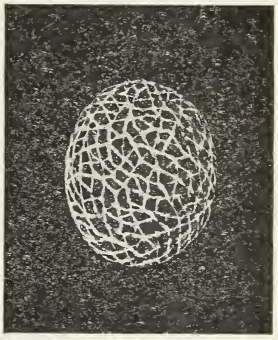


Fig. 6.—The alfalfa weevil: Cocoon. Much enlarged. (Author's illustration.)

When all the supply was exhausted, the head groped aimlessly about for a few seconds, then was applied to the caudal gland as before. The body would then straighten with a quick movement and almost instantly the thread would be again flowing as before. The new thread was guided skillfully across the meshes, rarely if ever following the line of a thread already laid. A very slight jar would cause a sudden halt for perhaps half a minute, then the operation would hesitatingly proceed. As the irregularly oval cocoon is too small in any diameter to allow the larva to straighten out, the larva moved about by thrusting its small head into a mesh, swinging the body into the desired position; the head would then be moved to another mesh and the operation repeated. The fluidity and amount of the silk must vary as spinning progresses, the silk becoming more viscous or less copious as the cocoon approaches completion.

The pupal period, according to Mr. Parks's notes, during the middle of May lasts about 9 days, the larvæ spinning their cocoons about 5 days before pupating. (A pupa is shown in fig. 7.) At the end

of the season, however, during August, when the temperature is higher, the pupal period averages only 3 days, the cocoon being spun only about 36 hours before the larva pupated. The adult leaves the cocoon about a day after transformation, and unlike others of this genus does not devour the cocoon. Although the insect has passed through its transformation from egg to adult the injury it causes is by no means ended. The beetles themselves not only feed upon the young growth (fig. 8), but gnaw off the bark of the stems, and, together with the larvæ still in the fields, in this way prevent the alfalfa from springing up for weeks after the first crop of hay has been removed. Two of such fields are shown in Plate V, figure 3, and Plate VI, figure 3, the ground being almost as bare of growing plants as in figure 1, Plate VIII, where the ground has been torn up with a spring-tooth harrow. The beetles sometimes cluster in great numbers upon a single plant, as illustrated in figure 8.

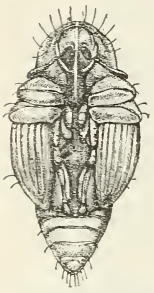


FIG. 7.—The alfalfa weevil: Pupa. Much enlarged. (Author's illustration.)

FOOD PLANTS.

In a series of experiments carried out by Mr. P. H. Hertzog, larvæ of *Phytonomus posticus* were placed in cages on various food plants, both alone and with alfalfa, and it was found that they fed freely upon the following plants, in combination with alfalfa:

Sweet pea, *Lathyrus odoratus;* Utah milk vetch, *Astragalus utahensis;* string bean, *Phaseolus vulgaris;* obtuse-leaved vetch, *Vicia* sp.; narrow-leaved vetch, *Vicia* sp.; white clover, *Trifolium repens;* red clover, *T. pratense;* alsike clover, *T. hybridum;* yellow sweet clover, *Melilotus indica*(?); whitesweetclover, *M. alba; Medicago lupulina; M. echinus; M. hispida nigra; M. hispida confinis; M. hispida terebellum; M. muricata; M. orbicularis; M. scutellata;* black locust, *Robinia pseudacacia;* fenugreek, *Trigonella fœnumgræcum.*

The following is a list of plants eaten by the larvæ when no other food was offered, but refused when offered together with alfalfa:

Hedysarum mackenzii; Astragalus oreophilus; downy lupine, *Lupinus*; sp. chick pea, *Lathyrus sativus; Vicia atropurpurea; Vicia dispema;* spring vetch, *Vicia sativa alba;* hairy or winter vetch, *Vicia villosa;* spider plant, *Cleome serrulata.*

FIG. 8.—The alfalfa weevil: Adults clustering on and attacking sprig of alfalfa. About natural size. (Author's illustration.)

The following plants were refused by the larvæ even when no other food was offered:

Everlasting pea, *Lathyrus latifolius;* round-leaved mallow, *Malva rotundifolia;* birdsknot grass, *Polygonum aviculare;* garden pea, *Pisum sativum;* lamb's-quarters, *Chenopodium album;* purslane, *Portulaca oleracea;* prickly lettuce, *Lactuca scariola*, perhaps var. *integrata;* ground cherry, *Physalis longifolia*(?); bitterweed, *Ambrosia psilostachya;* bitterweed, *Ambrosia trifida integrifolia;* rough pigweed, *Amaranthus retroflexus.*

MIGRATION AND DIFFUSION.

There are two periods during which the adult insects migrate, more or less aided by the winds and perhaps to a less extent by other agencies. Such as have not hibernated directly in the alfalfa fields become active in early spring and fly about freely, seeking such fields in which to deposit their eggs. This spring migration covers a considerable period of time—about six weeks, as estimated by Mr. Titus. As the females are more or less heavily laden with eggs, however, the flight of the individual is perceptibly shorter than in the second, or summer, migration, the season for which begins early in June and continues for three or four weeks. Another reason for the shorter flight in spring is that the beetles are searching about, not for places of hibernation, but for breeding places. Having found these, they naturally would not go farther unless carried by the winds. In case of a summer flight, however, the conditions are altogether different. This is the season during which most nomadic insects become more widely diffused. At this time the beetles fly high in the air and apparently over long distances. They are also to be observed crawling about in almost every situation, as with the larger species, *Hypera punctata,* which may be observed wandering aimlessly over the pavements in the midst of large cities. Then, too, they appear to float about freely on the surface of water, and are doubtless carried long distances down stream by the current. We know this is true in the case of irrigating ditches and canals, and it is also true of the larger species just mentioned in case of streams in the East. This habit of the beetles in hiding themselves away in any crevice or aperture that will accommodate them doubtless has considerable to do with their diffusion. As a matter of fact, however, it is absolutely impossible to lay down any law that appears to regulate the diffusion of the insect. There are instances where it would seem almost impossible to prevent the distribution of the pest, and yet most careful examination has failed to reveal anything of this sort. For a considerable time after the alfalfa weevil became abundant about Salt Lake and Murray hay was shipped from these points to Ely, Nev. This, too, in the midst of the season, when it would seem impossible to transport hay from these points to its destination without carrying greater or less numbers of the weevil. Notwithstanding this, years have gone by, and during the summer of 1911 two assistants examined the country about Ely most carefully without finding a single alfalfa weevil or any indications that it had ever existed there. While it is possible to account for the spread of the insect theoretically, we can not as yet account for its diffusion to the northeast into adjacent sections of Wyoming and Idaho. It does not appear to have entered Idaho by way of the Cache Valley, although Mr. Titus found beetles on a coal car at

Cache Junction in 1910. It does, however, occur in the Bear River Valley from Evanston, Almy, and Lyman, Wyo., northward into Bear Lake County in extreme southeastern Idaho. Previous observations would indicate that by a natural diffusion the insect has spread a distance of about 30 miles each year. As a matter of fact, the beetles are continually being found where least expected, and they have not been found where, judging from their habits, we would feel most confident of their occurrence.

The most rapid dispersion of the insect during the last two years has been toward the northeast from the original point of infestation in the Salt Lake Valley. Its injury is now noticeable wherever alfalfa is grown in the river valleys east of Ogden to the Wyoming State line and northward to the southern extremity of Bear Lake. It is known to occur, however, as previously stated, as far north as Cokeville, Wyo., and southward to Evanston and Lyman, where specimens were taken during the summer of 1911. This northeastward trend of diffusion in the weevil must be considered in connection with prevailing southwest winds at the time when the beetles are flying, and, in fact, careful search over the newly infested territory seems to render it highly probable that to this cause is due this northeastward diffusion. The finding of individual larvæ well scattered over Wyoming fields with little or no indications of introduction by human agencies, together with the finding of larvæ in an irrigated valley isolated from other cultivated crops by 35 miles of dry desert country, are conditions hard to explain in any other way than that the south winds of spring and summer have resulted in carrying flying beetles over low mountain ranges to fertile fields beyond. To just what extent the winds are able to carry the adults into new territory is not known, but at any rate migration in other directions has taken place much less rapidly.

FIELD EXPERIMENTS IN DESTROYING THE ALFALFA WEEVIL.

Several extended series of experiments in destroying the alfalfa weevil were carried out at various points in the infested territory in Utah, but only those that have shown the best results will here be mentioned.

Quite naturally, a measure that will destroy a greater or less number of the insects and at the same time encourage the growth of the plant, and is of practical application, will not only be the most attractive one to the farmer but will result in a double benefit. For this reason disking was looked upon as probably offering the best results. It was thought that by disking and spraying a more rapid growth of the alfalfa plants would be secured, and by following this with the use of a brush drag a great many of the larvæ would be crushed and destroyed. Mr. Ainslie's observations made in 1910

indicate, however, that the brush drag does not destroy as many of the larvæ as one would suppose, and for this reason some harsher measures have been put into application during the season of 1911.

Street-Sweeper Experiments.

The ordinary street sweeper, such as is used in our cities, appears to be a most thorough measure of destroying the pupæ. This much was determined by the Utah Experiment Station. A street sweeper (Pl. V, fig. 1) was used in a field on June 22, 1911. While examination showed that the result of this treatment, at this time, was to kill most of the larvæ and pupæ, it did not kill a great percentage of the adult weevils, which had already developed in large numbers. It would have been much better had this work been carried out about two weeks earlier; not only the condition of this field but of others in the neighborhood treated between June 14 and July 1 indicated that considerable good had resulted from this treatment even at this late season. On another farm, owned by Mr. Breeze, southwest of Salt Lake City, a field was swept with the street sweeper about the 14th of June with a view of interfering with the work of the weevil.

By July 7 the alfalfa in the Breeze field was about 20 inches high with very few weevils present. (See Pl. V, fig. 2.) Twenty days later the alfalfa was 30 inches high and in full bloom, being ready for the taking of a second crop. Just across the road from this farm was a field where no treatment whatever had been applied against the weevil. In this field the alfalfa plants were only about a foot in height and very much delayed (Pl. V, fig. 3). This seems to indicate that as a protection for the second crop the measure has considerable value. The drawback here is in the expense of a street sweeper, although of course where the members of a community club together, or in case of very large alfalfa fields of several hundred acres, the first cost of this sweeping machine would not constitute such an important item.

Wire-Brush Experiment.

A 13-acre field of alfalfa 7 years old had been disked in the spring of 1910. The first crop of alfalfa was reported to have been reduced to one-half by attack of the weevil. A weevil-collecting machine had also been used on this first crop, but there were still enough of the weevils left in the field to greatly retard the second crop. It was disked and dragged again and a fairly good yield of the second crop was secured. This was also true of the third crop in this same field.

On May 15, 1911, there was a good stand of alfalfa in this same field. One irrigation had at this date been applied. The plants were a little over a foot in height, and while at the time, May 15, they were in fairly good condition they were heavily infested with weevil larvæ. The gathering machine was used twice between the 17th and

25th of May, and observations made at the time indicate that while many of the full-grown larvæ were collected, most of the smaller ones were left among the buds. On May 29 the field received a second irrigation. The larvæ at this time were very abundant; the gathering machine, too, had retarded the growth of the plants by breaking off the growing tips and some of the plants themselves had been broken down by the collecting machine. As a result the alfalfa had apparently made little or no growth since about the 22d, and its value as forage was at that time rapidly decreasing.

A wire-brush machine (Pl. VI, fig. 1) was constructed by Mr. L. Hemenway by bolting about 30 pieces of No. 8 steel wire 7 inches long between iron clamps on each spring tooth of an old spring-tooth cultivator. The ground was gone over with one of these on June 1, as soon as the hay had been removed. The jumping action of the spring, together with the wire brushes, proved very effective in crushing larvæ and pupæ among the stubble. The field was then gone over with a plank leveler, shown in Plate VIII, figure 2, with square iron edges bolted to a plank. June 7, the field received another brushing with the wire-brush machine, which crushed cocoons and larvæ. By June 13 the second crop in this field had started nicely with very few weevils present. In another field near by no attempt had been made to treat it or to remove the weevil, and this field was taken as a check on the one under treatment. An examination at this time showed that when the former field was in good condition, with few larvæ, the field that had received no treatment was bare and brown from their attack.

On June 22 the second crop of alfalfa on the treated field was about 8 inches high, while the unworked field was still bare and its condition, on June 27, is shown in Plate VI, figure 3. By the 27th the alfalfa in the treated field was about 1 foot in height (see Pl. VI, fig. 2), the stand extra good, and the treatment had seemed to free the field from weeds and other foreign growth. By July 7 the plants were about 2 feet in height, while, of course, both the adults and larvæ could be found to some extent in this field. July 27 the second crop harvested 2 tons per acre, selling at $9 per ton in the field. The field at time of harvest of second crop is illustrated in Plate VII, figure 1. The unworked field, however, was making an inferior second crop, coming just a little in advance of the third crop in the treated field.

From the treated field there was also a fourth crop of hay secured. The field was photographed on October 9, 1911, and the yield of hay is illustrated in Plate VII, figure 2. The condition of the check field a few days later, October 12, is shown in Plate VII, figure 3; here the second and third crops were both not only badly damaged, but so delayed in growth of alfalfa that, as shown by the illustration, no fourth crop was secured at all.

FIG. 1.—Street sweeper in operation on alfalfa field after first crop was removed. Larvæ and pupæ were crushed by the rotary brush. Photographed June 14, 1911. (Original.)

FIG. 2.—Second crop ready to cut in the field on which street sweeper was used June 14, 1911. Good stand and good crop. Photographed July 27, 1911. (Original.)

FIG. 3.—Second crop of alfalfa growing on field where no treatment was given. Crop short and about two weeks behind that of the field shown in figure 2. Photographed July 27, 1911. (Original.)

FIG. 1.—Wire-brush cultivator in operation on alfalfa field after first crop was removed. The brushes crush the larvæ and pupæ on the ground at this time. Photographed June 7, 1911. (Original.)

FIG. 2.—Second crop of alfalfa growing nicely as a result of treatment given. (See fig. 1, above.) Larvæ and pupæ were killed, so that second crop suffered only slight injury. (Original.)

FIG. 3.—Condition of untreated fields about June. Photographed June 27, 1911. (Original.)

FIG. 1.—Second crop of alfalfa, estimated at 2 tons per acre, secured from field treated with wire-brush cultivator. Photographed August 2, 1911. (Original.)

FIG. 2.—Fourth crop of alfalfa secured from field where brush cultivator was used. Photographed October 9, 1911. (Original.)

FIG. 3.—Condition of field used as check (Pl. V, fig. 3). The second and third crops on this field made little growth and were much delayed, so what would correspond to the fourth crop was caught by frost. Photographed October 12, 1911. (Original.)

FIG. 1.—Alfalfa field after first crop was removed, severely disked preparatory to application of "mudding" process against the alfalfa weevil. Photographed June 21, 1911. (Original.)

FIG. 2.—Following the irrigation water with a drag, to "puddle" the weevils in the mud. Photographed June 22, 1911.

FIELD EXPERIMENTS AGAINST THE ALFALFA WEEVIL.

FIG. 1.—Second crop of alfalfa in field treated by "mudding" process. Crop growing well and not seriously damaged by the alfalfa weevil. Photographed June 10, 1911. (Original.)

FIG. 2.—Condition of untreated fields at time photograph shown in figure 1 was taken. The alfalfa weevils have prevented the second crop from starting. Photograph taken July 10, 1911. (Original.)

FIG. 3.—Patch of first crop left in field shown in figure 1, illustrating how the larvæ were disseminated from the first crop into the field where the weevil had been killed by the "mudding" process. Photograph taken July 10, 1911. (Original.)

FIELD EXPERIMENTS AGAINST THE ALFALFA WEEVIL.

Cultivation in Connection with Irrigation.

For an experiment to determine the value of cultivation in connection with irrigation in controlling the alfalfa weevil a field was selected on a farm belonging to Mr. Hansen, 1 mile southeast of Sandy, Utah, containing 16 acres. The soil was a light sandy loam. Some of the weevils had been noticed in this field in 1908 and also in 1909, while the first crop of 1910 was severely damaged and the second also suffered considerable loss. May 11, 1911, the field was irrigated, the infestation being considered heavy. The first crop was cut during the week ending June 10. The plants were about 9 or 10 inches high and the hay yielded less than 1 ton per acre of very poor quality. This field was again irrigated and the more elevated portion of it worked with a spring-tooth harrow while the surface was still soft from the irrigation. This treatment was repeated and when finished the field had very much the appearance of any cultivated field, little resembling a meadow. (See Pl. VIII, fig. 1.)

On June 22, while the land was still soft and muddy, a light irrigation was given it, so that the water collecting in the lower portion of the field stood to a depth of 2 or 3 inches. Four horses were hitched to a plank leveler and dragged through this mud, as shown in Plate VIII, figure 2. This thoroughly "puddled" the weevil in all of its stages beneath the surface.

By the 30th of June a second crop was starting very nicely while neighboring untreated fields were being retarded by the continued attacks of the weevil. Ten days later the plants were about 12 inches high with very few of either larvæ or beetles present. However, a patch had been left uncut and unworked in one corner of this field and here the first crop of alfalfa was still standing. (See Pl. IX, fig. 3, at the right.)

There were a great many larvæ and beetles on this patch, which disseminated themselves into the growing alfalfa where the mudding process had been practiced, destroying a strip about 1 rod in width, clearly shown in Plate IX, figure 3. The second crop in this field, July 10, 18 days after the mudding experiment was carried out, was about 14 inches high. (See Pl. IX, fig. 1.)

In a near-by untreated field at the same time, four weeks after the first cutting was made, the condition is shown in Plate IX, figure 2.

Burning Machine.

Several field experiments were carried out with a machine constructed with the idea of burning over alfalfa fields after the removal of the first crop for the purpose of destroying the weevils in any stage of development remaining in the field. The machine, as shown in Plate X, figure 1, consisted of an iron frame 9 feet square, 12 inches

high in front, and adjustable in the rear. The top was of light sheet iron bolted to the frame.

Oil was pumped from a barrel in the conveyance to which this machine was attached and forced through a rubber hose into a supply pipe which fed the nozzles and burners underneath. The oil under pressure came forth from the burners as a mist of fire blowing into the stubble and against the ground.

The sheet-iron cover served to hold the heat down while this oven passed slowly over the surface. In its unperfected state the machine did effective work and offered ideas of value, warranting the construction of more efficient burners.

In fields where there was a clean stand of alfalfa stubble this machine did very well in burning vegetation and destroying all insect life above the surface of the ground. Where many weeds, especially dandelions, were present, the insects found protection under the green leaves. Where parts of fields were burned over, the unburned area showed no growth for several weeks on account of the continued weevil attack. The burned area turned green within a very much shorter time.

REDUCTION IN QUALITY OF HAY CAUSED BY THE ALFALFA WEEVIL.

While studying the alfalfa weevil on various farms in the Salt Lake Valley during the month of April, 1911, it was found that many farmers, through a shortage of forage, were feeding the weevil-injured hay of the first crop to their horses. This hay contained so many old cocoons and was so dusty from larval excrement and dead bodies of weevil larvæ as to render it unfit as feed for horses. On several occasions horses were observed coughing from the effect of this dust. In fact, many farmers consider the first crop from severely infested fields almost valueless as horse feed.

On June 12, 1911, at Alpine, Utah, when the new hay from the first crop was fed to work horses these began coughing almost immediately after starting to feed upon this injured hay. The hay contained large numbers of dead weevil larvæ, some still on the skeletonized leaves and some in the freshly spun cocoons. On September 13 hay from the first crop, in stack, was examined at Layton, Utah, and found to be very dusty, containing many dead weevil larvæ and also pupæ.

NATURAL ENEMIES.

The natural enemies of the alfalfa weevil consist of vertebrates and invertebrates. The former have been studied by assistants of the Bureau of Biological Survey, and a list of species observed to attack the weevil is given herewith.

The invertebrate enemies are divided between native species and those imported from Italy, the native being largely predaceous and the foreign all parasitic.

Besides these, there are two fungous enemies, both of which affect the insect to a greater or less degree.

Invertebrates.

When a foreign species, like the alfalfa weevil, is introduced into a new country, some time is required for the native insects to find out that it is suitable for food, precisely as man himself would under the same circumstances have to learn what products of a new country were edible. Besides, he would most likely cultivate a taste for some of these things which at first were distasteful to him. Thus it is that native insect foes of introduced species begin slowly at first to prey upon them.

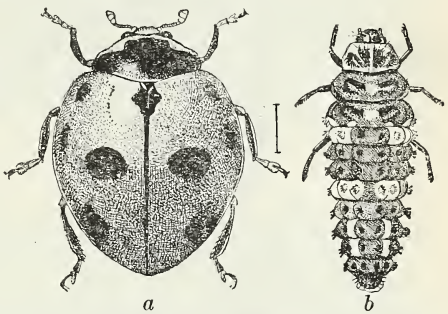


Fig. 9.—Nine-spotted lady-beetle (*Coccinella 9-notata*): *a*, Adult; *b*, Larva. Much enlarged. (From Chittenden.)

The following native predaceous insects have been found attacking and devouring the alfalfa weevil:

Predaceous enemies.

A species of tiger-beetles, *Cicindela imperfecta* Lec., was in one instance observed to feed upon an alfalfa weevil larva in the field. Several other individuals belonging to the same species when taken to the laboratory readily devoured larvæ.

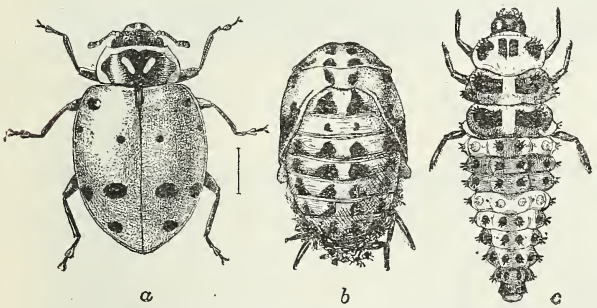


Fig. 10.—Convergent lady-beetle (*Hippodamia convergens*): *a*, Adult; *b*, pupa; *c*, larva. Enlarged. (From Chittenden.)

Three species of lady-beetles, *Coccinella 9-notata*, Hbst. (fig. 9), *Hippodamia spuria* Lec., and *H. convergens* Guér. (fig. 10), in the larval stage attacked and devoured half-grown larvæ of the alfalfa weevil in the fields. Larvæ so taken were brought into the laboratory and adults reared, from which specific determinations were made. In case of *H. spuria* the adult was also observed devouring larvæ in the field.

The malachid beetle, *Collops bipunctatus* (fig. 11), was repeatedly observed feeding upon the weevil larvæ in the fields.

The tenebrionid beetle, *Eleodes sulcipennis* Mann., was accused by farmers of feeding upon the larvæ of the weevil and when taken to the laboratory it readily did this in confinement. An allied species, *E. suturalis* Say, was observed by Mr. E. O. G. Kelly to devour chinch bugs in the neighborhood of Wellington, Kans. In the latter instance the beetles seemed to prefer the partially decaying leaves of corn under which the chinch bugs were hiding. It is probable that while these insects may devour a few of the weevil larvæ they prefer other and vegetable food.

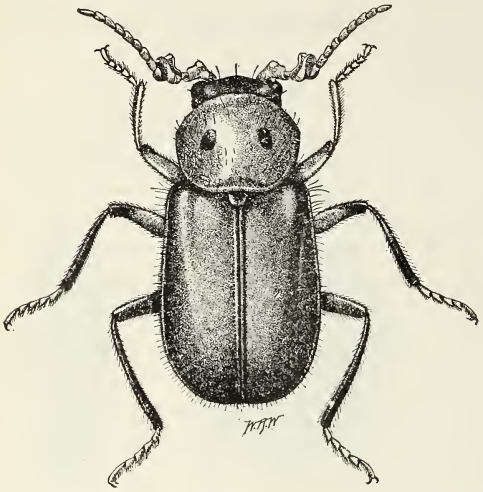


FIG. 11.—The two-spotted Collops (*Collops bipunctatus*): Adult. Enlarged. (Original.)

The predaceous mite, *Pediculoides ventricosus* Newp. (figs. 12, 13), was introduced from Indiana in March, 1911, but was afterwards

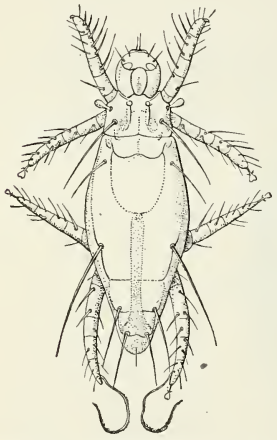


FIG. 12.—*Pediculoides ventricosus*, a mite predatory on the alfalfa weevil: Adult female before the abdomen has become inflated with eggs and young. In this condition the mite is nomadic and predatory. Greatly enlarged. (Redrawn from Brucker.)

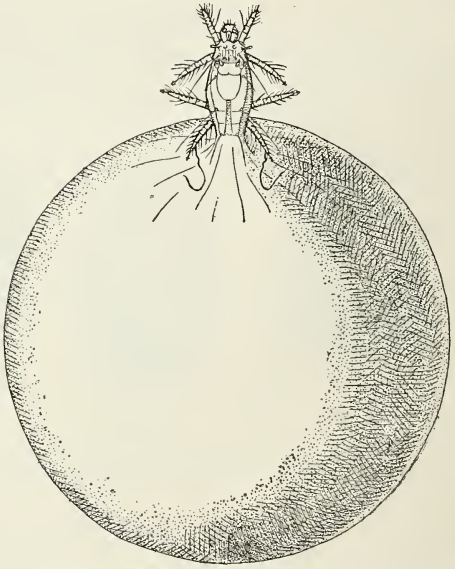


FIG. 13.—*Pediculoides ventricosus:* Adult female after the abdomen has become inflated with eggs and young. Greatly enlarged. (Redrawn from Brucker.)

found a sufficient distance away from the points of introduction to show plainly that it was already an inhabitant of Utah. The results

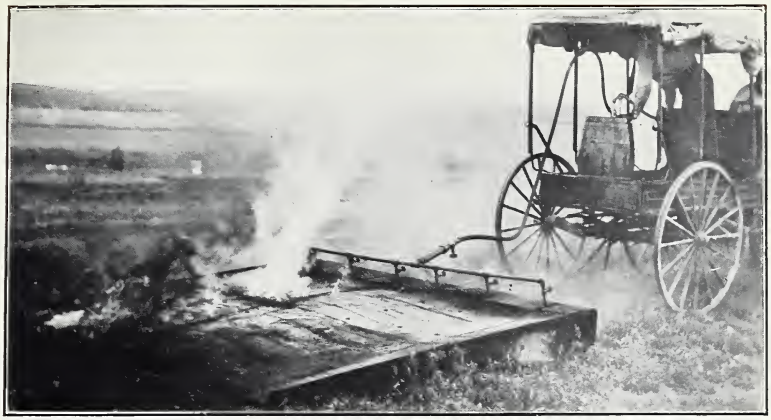


FIG. 1.—BURNING MACHINE EXPERIMENTED WITH AS A METHOD OF DESTROYING THE ALFALFA WEEVIL. (ORIGINAL.)

FIG. 2.—BOXES CONTAINING PARASITES OF THE LARVÆ AND PUPÆ OF THE ALFALFA WEEVIL, SHOWING HOW THIS MATERIAL WAS IMPORTED INTO THE UNITED STATES FROM ITALY. PHOTOGRAPH TAKEN JUNE, 1911. (ORIGINAL.)

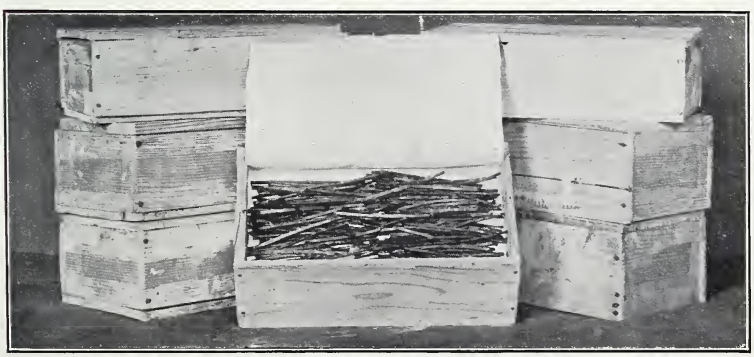


FIG. 3.—BOXES OF PARASITE MATERIAL IMPORTED FROM ITALY WHICH CONTAIN EGG PARASITES OF THE ALFALFA WEEVIL. PHOTOGRAPH TAKEN MAY, 1911. (ORIGINAL.)

of experiments with this mite, which is so effective in destroying the jointworm in the East, were unsuccessful, as it was found that the mites would not attack either the larvæ or the pupæ. They fed freely upon the eggs of the weevil, where these were easily accessible, but they seemed unable to gain access into many of the egg masses through the ordinary egg punctures. A single egg did not furnish sufficient food to bring one mite to maturity, and it would therefore necessarily perish; but where there were clusters of eggs in contact with each other, the female mite was able to shift her body about sufficiently to devour more than one egg and was thus enabled to reproduce. In the field, when placed in cages with an abundance of eggs of the alfalfa weevil, the mites appeared to make considerable headway in overcoming the weevil, but in no case could the effects of their attack be traced farther than 2 feet from the cage where they had been confined in the fields.

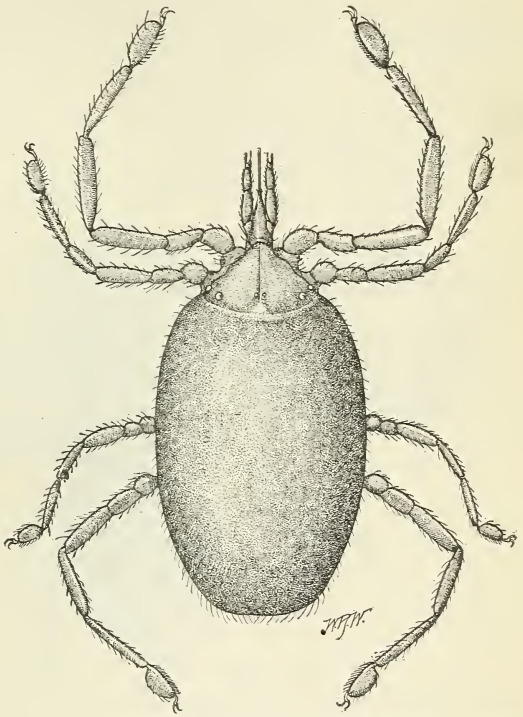


FIG. 14.—A predaceous mite, *Erythræus arvensis:* Adult. Greatly enlarged. (Original.)

A little mite (Trombidium) was found attached to the adult weevil beneath the wing covers, and while it was observed quite commonly in late summer and fall, so far as observations indicated it did not appear able to kill the host insect. A predaceous mite, *Erythræus arvensis* Banks (fig. 14), was found by Mr. Ainslie feeding on eggs of the weevil in the egg punctures. The economic value of this species is as yet very obscure. Spiders are occasionally found feeding upon the larvæ in the fields. Lace-wing flies (Chrysopa) fed upon the larvæ in confinement when forced to do so, but preferred aphides. They were not observed to attack the weevil in any form in the fields.

A NATIVE TRUE PARASITE.

Only one specimen of a single species of a true parasite of the alfalfa weevil has so far been found in America. This was described by Mr. Viereck as *Ænoplegimorpha phytonomi*. It was found August 30, 1911, at Hoytsville, Utah, in the form of a cocooned pupa within the cocoon of the alfalfa weevil. The specimen was picked up from the surface of the ground in a badly infested alfalfa field and the adult parasite reared. The adult emerged September 3.

INTRODUCED PARASITES.

Several species of parasites were sent over from the vicinity of Portici, Italy, by Mr. W. F. Fiske during April, May, and June, 1911.

FIG. 15.—*Anaphes* sp., a mymarid egg parasite of the alfalfa weevil: Adult male; female antenna above at right. Greatly enlarged. (Original.)

The egg parasites were obtained by collecting stems of alfalfa containing eggs of the alfalfa weevil, placing these in boxes (Pl. X, fig. 3), and transporting them by cold storage on steamers bound for New York. On arrival from Europe they were promptly forwarded by refrigerator express to their destination, Salt Lake City, Utah, where they were at once taken either to the laboratory at Salt Lake City (Pl. XIII, fig. 1) or to the laboratory at Murray (Pl. XIII, fig. 2).

Parasites that attack the weevil after it has hatched and before it has developed to the adult were handled in much the same manner. The boxes in which they were consigned are shown in Plate X, figure 2. The time required to transport these boxes from Portici, Italy, to Salt Lake City, Utah, was from 16 to 21 days.

Egg Parasites.

There were two egg parasites, one, a true egg parasite developing within the egg, and the second, a parasite the eggs of which are probably deposited in the alfalfa stems among, but not in, the eggs. The larva of the latter is predaceous on the masses of weevil eggs as placed by the female weevil, and among them it develops to the adult.

MYMARID EGG PARASITE.

A mymarid egg parasite, *Anaphes* sp. (fig. 15), was found in all of the seven shipments received from Italy. It was received in all stages of development, except perhaps the egg and adult, and was either left in the same boxes, these being perforated with holes and

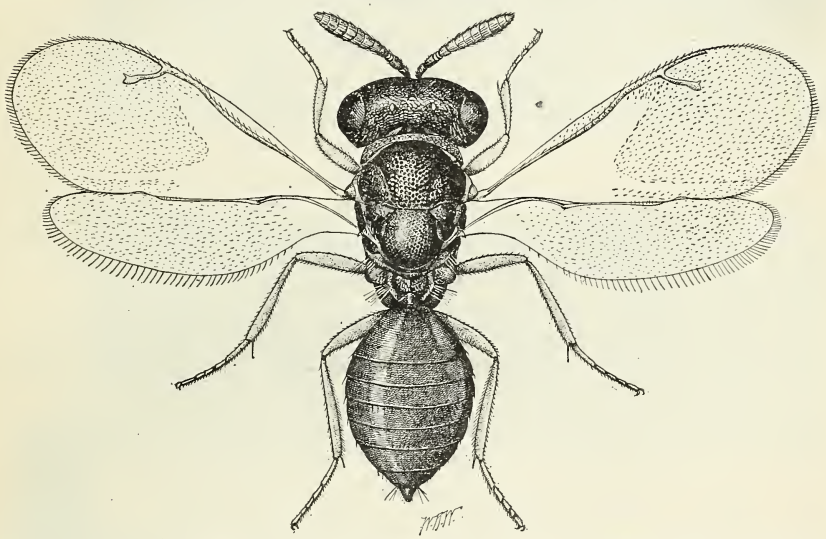


Fig. 16.—Imported pteromalid egg parasite of the alfalfa weevil: Adult. Greatly enlarged. (Original.)

glass tubes inserted (Pl. XI, fig. 2), or placed in specially prepared boxes (Pl. XI, fig. 3) which were also perforated and had glass tubes inserted. The parasites were reared from this imported material, and from the parent stock two generations were reared on American egg masses of the alfalfa weevil. The third generation, together with others of the first and second generations and natives from later shipments, was placed in field reproduction cages (Pl. XII, fig. 3) to the number of about 300. These cages were overstocked with eggs by confining numbers of weevils in them. After about 10 days the covers to these cages were removed, thus allowing the generation of parasites that developed within them to escape and scatter freely over the fields.

PTEROMALID EGG PARASITE.

A pteromalid egg parasite (fig. 16) was likewise found in all of the seven importations. The larva (fig. 17) feeds externally on the egg masses in the alfalfa stems, later transforming to the pupa (fig. 18).

The disposal and management of this species did not differ from that followed with the preceding, except that some of them were received too late in the season to use in the low valleys because the majority of the eggs of the weevil had already hatched. Owing to this the parasites were taken to places in higher elevations where eggs of Phytonomus were still abundant. Approximately 460 were placed in field cages like those previously mentioned and treated in the same way.

FIG. 17.—Larva of pteromalid egg parasite of the alfalfa weevil. Greatly enlarged. (Original.)

Mr. Fiske found this species to be very effective in controlling the alfalfa weevil in Italy.

PARASITES OF LARVÆ AND PUPÆ.

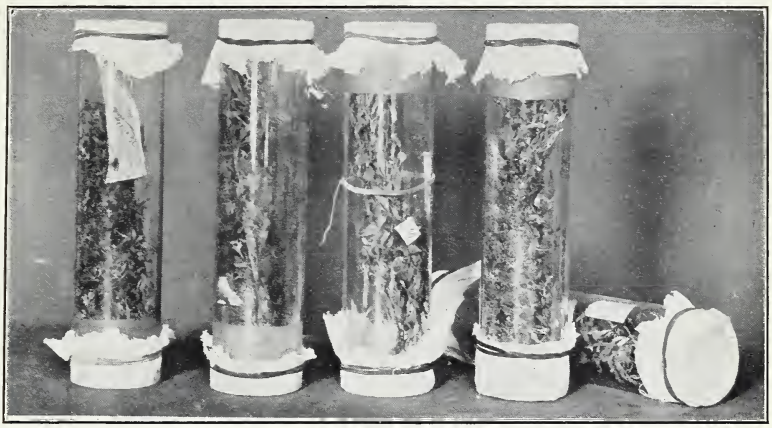
The parasites of the larvæ and pupæ of the alfalfa weevil, which were five in number, did not appear in the earlier consignments from Italy and were confined to the last three received at Salt Lake City May 16 to June 3. In these three shipments were metal boxes (Pl. X, fig. 2), which included only the cocoons of the alfalfa weevil. These boxes were especially devised to guard against the accidental escape of adult insects of any species en route.

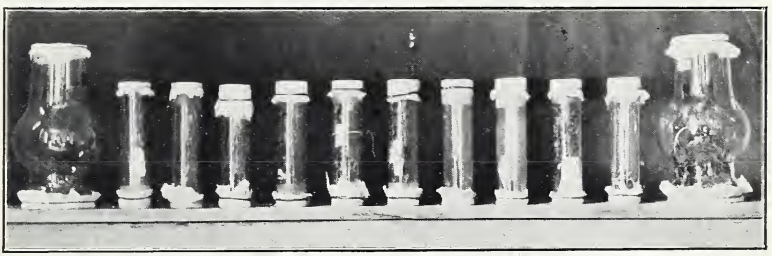
After being removed from the boxes in which the cocoons were received, they were placed in parasite boxes of the larger type (Pl. XI, fig. 3), where the parasites emerged and were separated from the weevils that had developed en route. Both weevils and parasites on emerging from the cocoons in the box would seek the light and appear in the glass tubes shown in the illustration, where they were readily separated and the weevils killed. The parasites were then transferred to glass cages (Pl. XI, figs. 1, 4) which had been previously well stocked with larvæ and cocoons.

FIG. 18.—Pupa of pteromalid egg parasite of the alfalfa weevil. Greatly enlarged. (Original.)

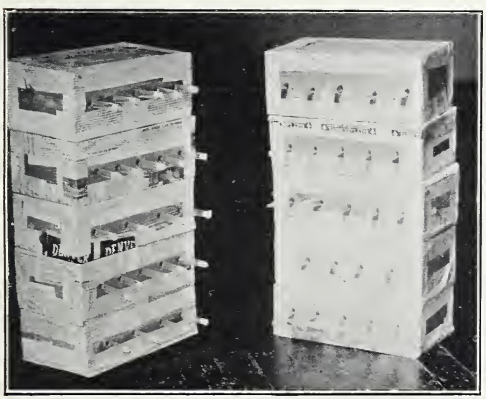
PTEROMALID LARVAL PARASITE.

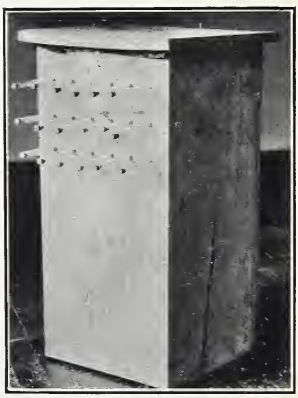
A pteromalid parasite of alfalfa weevil larvæ (fig. 19, female; fig. 20, male) was received in only the later consignments. Thus far it has not been possible to determine the species. In the laboratory rearings, preparatory to placing the parasites in the field cages, and later, the species was carried through five generations. (Fig. 21, *a* shows the pupa of the alfalfa weevil, with the egg (fig. 21, *b*) as it is placed on the pupa; fig. 22 shows the larva, and fig. 23 shows it destroying the pupa of the alfalfa weevil; fig. 24 shows the pupa of the parasite itself.) In order to accomplish this, however, it was necessary to secure weevil larvæ, as hosts for them, from high



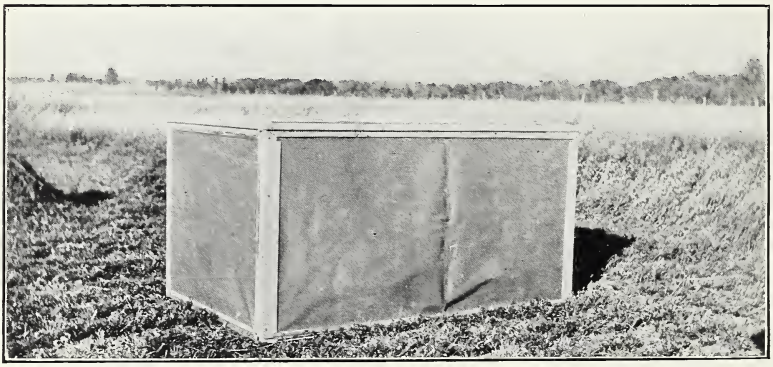


FIGS. 1 and 4.—Types of cages in which larval and pupal parasites of the alfalfa weevil were reared in the laboratory. Photograph taken during June, 1911. (Original.)





FIGS. 2 and 3.—Boxes sealed and fitted with glass tubes into which imported parasites emerged and were separated in the laboratory. Photograph taken during May and June, 1911. (Original.)



FIGS. 1 AND 2.—FIELD CAGES USED IN HIBERNATION EXPERIMENTS ON THE ALFALFA WEEVIL. (ORIGINAL.)

FIG. 3.—PLANTING A COLONY OF IMPORTED PARASITES OF THE ALFALFA WEEVIL IN UTAH IN AN ALFALFA FIELD. PHOTOGRAPH TAKEN DURING JUNE, 1911. (ORIGINAL.)

elevations and bring these into the laboratory, thus supplying them artificially. There were 230 individuals liberated in field cages, the coverings of which were later removed, and 49 liberated directly

FIG. 19.—Pteromalid parasite of larva and pupa of the alfalfa weevil: Adult female. Greatly enlarged. (Original.)

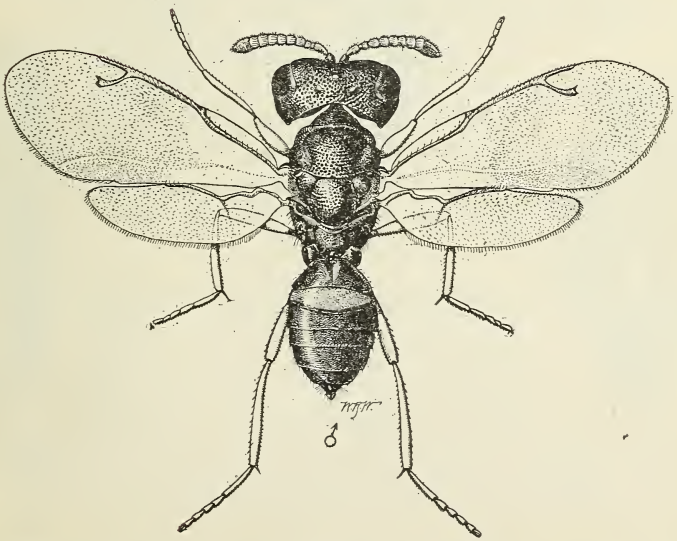


FIG. 20.—Pteromalid parasite of larva and pupa of the alfalfa weevil: Adult male. Greatly enlarged. (Original.)

into the open field. Observations have since shown that this species has actually colonized itself in the field; whether temporarily or permanently it remains to be seen.

OTHER PARASITES.

The following three parasites came mainly in the last two shipments from Italy. The adult of one species (*Canidiella curculionis* Thoms.) (fig. 25) oviposits in the larvæ of the alfalfa weevil in different stages of development, but the offspring therefrom emerge from the cocoon spun by the weevil, the cocoons of the parasite always showing through the meshes of the cocoon of the weevil (see fig. 27). This species has two generations annually and hibernates as cocooned larvæ. The alfalfa stems from which the three species of parasites of this group were reared were also infested by *Apion pisi* Fab., and therefore some or all of the group may perhaps also parasitize this latter insect. Owing to its small size, however, as compared to the parasites, this seems rather unlikely. The two additional species reared with the preceding are not definitely determinable, but one is *Phygadeuon* sp., and the other may prove to be *Mesochorus nigripes* Ratz. Of this latter species Mr. T. W. Wassiljew, a Russian entomologist, under date of February 6, 1911, wrote us:

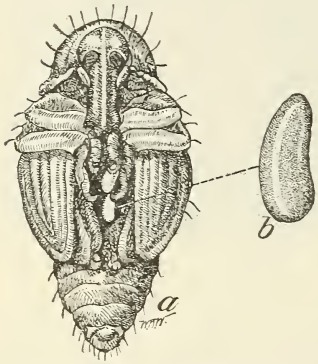


FIG. 21.—Pteromalid parasite of larva and pupa of the alfalfa weevil: *a*, Enlarged pupa of alfalfa weevil with eggs of parasite in place; *b*, egg, greatly enlarged. (Original.)

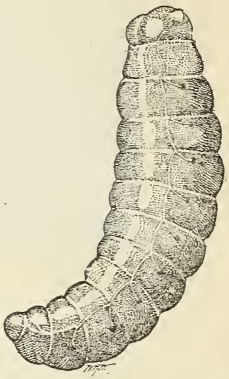


FIG. 22.—Pteromalid parasite of larva and pupa of the alfalfa weevil: Larva. Greatly enlarged. (Original.)

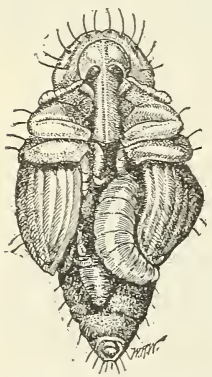


FIG. 23.—Larva of pteromalid parasite attacking pupa of alfalfa weevil. Enlarged. (Original.)

FIG. 24.—Pupa of pteromalid parasite shown in figures 22 and 23. Greatly enlarged. (Original.)

> I wish to say that I am able to give you only one instance of a parasite having been found, and that was in the vicinity of Taschkent (Turkestan), where I noticed in the past year [1910] that over 20 per cent of the larvæ of *P. variabilis* were attacked by an Ichneumon parasite. Unfortunately I do not know the name of this species of parasite at the present time, other than that it belongs to the Ichneumonidæ. Judging from the elliptical, thick-shelled cocoon it might possibly have been *Mesochorus nigripes* Ratz., which Mr. Ratzeburg (The Ichneumonidæ, III, p. 120) gives as a parasite of *P. rumicus*.

All of these parasites resemble each other to a certain degree, and figure 25 will suffice to illustrate them, for the present at least. At the present stage of this experiment in introducing parasites of the

alfalfa weevil the possibility of permanent establishment and future efficiency in the case of these species seems rather more encouraging than in case of the others. During June, 1911, 40 individuals reared from imported cocoons were placed in field cages artificially overstocked with weevil larvæ, the cage covers being removed later. Besides this, there is at present on hand a considerable amount of hibernating material (Pl. XII, figs. 1, 2) artificially reared in the Murray laboratory (Pl. XIII, fig. 2), which will be allowed to escape, naturally, into the alfalfa fields.

FIG. 25.—*Canidiella curculionis*, a parasite of the alfalfa weevil: Adult female; lateral view of abdomen of same below, at right. Enlarged. (Original.)

The parasite *Itoplectis masculator* Fab. (fig. 26) differs from the preceding by reason of the fact that it pupates entirely within the pupa of its host. It is known to be a primary parasite, but the number so far secured is too limited to warrant any discussion regarding it, or any predictions as to its future in America.

Of the eighth and last of these parasites, *Hemiteles* sp., very little is known either in Europe or America, and with the obscurity surrounding its habits it may prove to be either a primary or secondary parasite, a friend or an enemy of the others. It is therefore being handled with the utmost caution, none having been liberated either in the fields or in field cages.

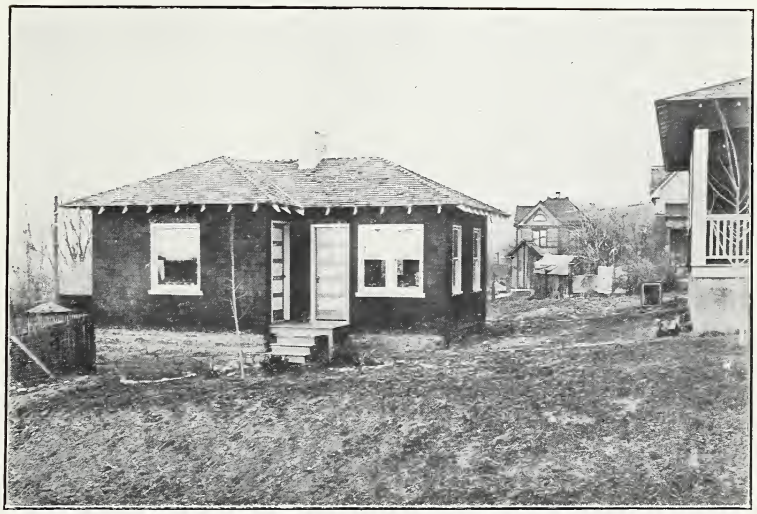
Vertebrates.

During the season of 1911 the Biological Survey, at the suggestion of the writer, kindly detailed an assistant, Mr. E. R. Kalmbach, to study the bird and other vertebrate enemies of the alfalfa weevil, and the following is a list of vertebrates found to feed on the alfalfa weevil in Utah, as determined by Mr. Kalmbach, May 7, 1911, to July 25, 1911.

Wilson's phalarope, *Steganopus tricolor;* killdeer, *Oxyechus vociferus;* valley quail, *Lophortyx californica vallicola;* mourning dove, *Zenaidura macroura carolinensis;* red-shafted flicker, *Colaptes cafer collaris;* Arkansas kingbird, *Tyrannus verticalis;* Say's

Fig. 26.—*Itoplectis masculator,* a parasite of the alfalfa weevil: Adult female; lateral view of first abdominal segment at right. Much enlarged. (Original.)

phoebe, *Sayornis sayus;* Traill's flycatcher, *Empidonax trailli;* desert horned lark, *Otocoris alpestris leucolæma;* magpie, *Pica pica hudsonia;* bobolink, *Dolichonyx oryzivorus;* cowbird, *Molothrus ater;* yellow-headed blackbird, *Xanthocephalus xanthocephalus;* thick-billed red-winged blackbird, *Agelaius phœniceus fortis;* Western meadowlark, *Sturnella neglecta;* Bullock's oriole, *Icterus bullocki;* Brewer's blackbird, *Euphagus cyanocephalus;* house finch, *Carpodacus mexicanus frontalis;* English sparrow, *Passer domesticus;* Western vesper sparrow, *Poœcetes gramineus confinis;* Western savannah sparrow, *Passerculus savannarum alaudinus;* Western lark sparrow, *Chondestes grammacus strigatus;* white-throated sparrow, *Zonotrichia albicollis;* Brewer's sparrow, *Spizella breweri;* Western chipping sparrow, *Spizella socialis arizonæ;* desert song sparrow, *Melospiza melodia fallax;* green-tailed towhee, *Oreospiza chlorura;* black-



FIGS. 1 AND 2.—LABORATORIES OF THE BUREAU OF ENTOMOLOGY, U. S. DEPARTMENT OF AGRICULTURE, AT SALT LAKE CITY AND MURRAY, UTAH. (ORIGINAL.)

headed grosbeak, *Zamelodia melanocephala;* rough-winged swallow, *Stelgidopteryx serripennis;* sage thrasher, *Oreoscoptes montanus;* Western robin, *Planesticus migratorius propinquus;* Rocky Mountain toad, *Bufo lentiginosus woodhousi;* leopard frog, *Rana pipiens;* salamander, *Amblystoma* sp.

Fungous Enemies.

Whenever the larger species *Hypera punctata* (fig. 2) becomes excessively abundant east of the Mississippi River, myriads of these larvæ may be observed coiled about the uppermost tip of blades of grass or similar vegetation, where they soon die and become black. These are apparently destroyed by a fungus, *Empusa sphærosperma.* When investigations of the alfalfa weevil were first undertaken there were great numbers of these dead and dying larvæ to be found in Washington, D. C., in Potomac Park. They were gathered up and sent out to Salt Lake City and placed in the hands of Mr. Ainslie with the hope of introducing this fungus among the larvæ of the alfalfa weevil. The experiment appeared to have been a failure, and it was thought that the climate of Utah was too dry to enable this fungus to exist there. Later this larger species was found in Utah, as has already been stated, and during the spring of 1911 the fungus was found in the vicinity of Salt Lake City. Apparently, however, the fungus does not affect the larvæ to the same extent that it does here in the East, except after these have reached their full size and constructed their cocoons. Larvæ of the alfalfa weevil (fig. 5) and pupæ (fig. 7) soon began to be observed in the cocoon (fig. 6) dead and thoroughly permeated with this fungus. No individuals in any case were found dead excepting within their cocoons. On June 13 in the vicinity of Salt Lake City it was estimated that one-fifth of the cocoons contained dead larvæ or pupæ. In the Weber Valley, about Hoytsville, Utah, on the last of August, it was found that of 580 cocoons examined 258, or 44.5 per cent, were dead, partly at least because of infestation by this fungus. Examination at another point showed that 38 per cent had apparently died from the same cause. To all appearances, then, this was more effective in killing the alfalfa weevil than all other natural enemies combined.

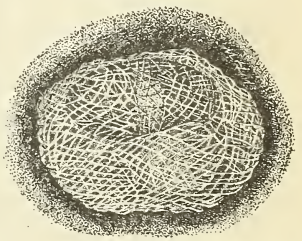


Fig. 27.—Cocoon of the alfalfa weevil showing cocoon of the parasite *Canidiella curculionis* within. Much enlarged. (Original.)

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